# A METHOD OF AND APPARATUS FOR FORMING A PLASTIC LINED TUNNEL

## FIELD OF THE INVENTION

This invention relates to a method of and apparatus for forming a plastic lined tunnel.

## BACKGROUND OF THE INVENTION

**[0001]** Typically, drains and tunnels are lined with plastic to provide corrosion resistance and a smooth internal bore so as to minimise pumping losses.

**[0002]** For large diameter drains and tunnels, the plastic liner is typically made by spiral winding ribbed plastic strip onto itself so as to form a spiral wound tube, the strip edges being formed so as to either engage complementary edge portions or to join the edges with a joining strip. The plastic strip may be forced into a spiral configuration inside an internal forming means such as illustrated in Australian Patent No. 530251 or it may be wound about a mandrel of the desired diameter such as is illustrated in US Patent No. 3,606,670.

**[0003]** Mostly, such plastic linings are utilised for repair of old drains and tunnels and thus it has also been proposed to form the liner directly into the tunnel being repaired so that the liner is advanced through the tunnel as the liner is formed. Such an arrangement is shown in Australian Patent No. 57422/98.

## BRIEF SUMMARY OF THE INVENTION

**[0004]** We have now found a method of and apparatus for forming a plastic lined tunnel which will be efficient and reliable in use.

**[0005]** According to one aspect of the present invention there is provided a method of forming a plastic lined tunnel including:

positioning a tube section of plastics material in a tunnel portion to be lined;

positioning a removable wall portion of an internal form assembly in the tube section to provide a temporary base wall wherein the internal form assembly further includes a collapsible wall portion;

engaging the base wall with at least one wall of the tunnel to retain the tube section in position;

transporting the collapsible wall portion along the temporary base wall into position for engagement with the temporary base wall within the tube section;

erecting the internal form assembly into an operative condition within the tube section as to conform the tube section to its desired shape;

introducing grout between the outer surface of the tube section and the tunnel wall so as to substantially fill the void therebetween and to retain the tube section in position;

collapsing the internal form assembly and removing the internal form assembly from the lined tunnel portion.

**[0006]** Suitably the tube section may be formed of any plastics material which can provide the chemical and physical properties to ensure sufficient corrosion resistance and toughness necessary for the application. When the application requires minimized pumping losses, the tube section is formed with a smooth internal surface and a keyed outer surface for improving the bond between the tube section and the grout. In one embodiment the keyed outer surface may simply be a grooving or roughness on that surface. Alternatively the outer surface may have one or more key members thereon for interlocking the tube into the grout placed between the tube section and the tunnel wall.

**[0007]** A suitable tube section may be formed with a series of encircling flanged ribs about its outer surface for interlocking the tube into a grout placed between the tube section and the tunnel wall. Alternatively it may be formed with a plurality of individual projections tabs or ties about its outer surface for interlocking the tube into a grout.

**[0008]** Preferably the tube section is a spiral wound tube produced from a strip of plastics material having T-shaped ribs extending about its external surface. Suitably the spiral joint between edges of the strip from which the tube is formed is welded, either internally or externally and preferably internally in a groove formed between the mating edges of the strip.

It is also preferred that the strip interlocks along mating edges and each interlocking formation has an external return rib for interlocking with the grout.

[0009] The tube section may be prefabricated and transported to the open end of the tunnel. Alternatively bales of plastic strip which can be formed into the tube sections may be transported to a fabrication unit adjacent the open end of the tunnel where the tube section may be fabricated. Suitably the tube section is introduced from one end of the tunnel and positioned within the tunnel remote from that one end. Subsequent tube sections may be introduced and positioned in abutment with the preceding tube section and the internal form assembly may be moved progressively from tube section to tube section toward that one end. The tube section may be positioned in the tunnel portion by any convenient means such as by a rail mounted tube carrier where the rails are located temporarily or permanently fixed to the tunnel. The tube carrier may have forks suitable for carrying the tube section, which forks permit fine control over the position and orientation of the tube section to facilitate placement of the tube section within the tunnel portion.

[0010] Abutting tube sections may be joined to one another by any convenient means such as by being adhered, taped or overlapped and mechanically fastened. Most suitably the tube sections are joined to one another by a welding process.

[0011] The exposed end of tube section forming a liner may be provided with locating means such as an external collar to form a socket into which the introduced end of the next tube section may spigot so as to align the abutting tube sections.

[0012] The collar may be continuous or gapped or otherwise formed so as to allow grout to extend into the void between the collar and the keyed outer surface of tube sections formed with interlocking means.

[0013] The internal form assembly suitably may comprise a series of segments including upper segments pivotally connected to one another as the collapsible wall portion which is engageable with a temporary base wall, composed of a segment or segments. The collapsible wall portion may be carried on a carriage which may move along the base wall.

[0014] Suitably such a carriage may include transport means which extends beyond a tube section for transporting a base wall segment from beyond one end of a tube section to beyond the other end of the tube section for shifting the base wall segment or segments from a previously lined tunnel portion, through an adjacent lined section into a tube section introduced into an unlined tunnel portion.

[0015] Suitably the base wall is formed in segments which may be lifted from one longitudinal edge or for rotation to an upstanding attitude so as to lie alongside the carriage for transport therepast.

[0016] The base wall may be engaged with at least one wall of the tunnel by a locating means which extends beyond the ends of the tube section or through supports extending through the tube section. Suitably the form of the tube section is cylindrical and the base wall is located substantially coaxially with the tunnel.

[0017] The internal form assembly may be erected into an operative condition to conform the tube section to the desired shape by any convenient means. Where the collapsible wall portion comprises hinged segments, the end segments may be engaged with the base wall and the collapsible wall portion erected by urging the remaining segments into engagement with the remainder of the tube section. The ends of segments may be shaped such that once erected the segments hold themselves in the desired shapes. These segments may take the form of overcentre tabs for ease of erection and collapse.

[0018] The grout may be introduced into the space between the outer surface of the tube section and the tunnel wall in any suitable manner so as to substantially fill the void therebetween and to retain the tube section in position. Suitably the grout is concrete which is pumped into position from a supply tube extending along the top outer surface of the tube sections. The hose may have a concertina or other retractable support in the tunnel to which it is retracted after filling the void which may extend about a plurality of tube sections.

**[0019]** The internal form assembly may be collapse by any convenient means and will generally follow the reverse process to the erection of the internal form assembly.

**[0020]** In a preferred embodiment there is provided a continuous method for forming a plastics lined tunnel whereby the internal form assembly is moved into an adjoining portion of the tunnel into which a tube section has been positioned so as to progressively form a continuous plastic lined tunnel.

**[0021]** In another aspect this invention resides broadly in a ribbed plastic strip for forming spiral wound tubing having complementary edge formations which engage to form the spiral wound tube and each edge formation having an projection adapted for interlocking engagement with surrounding grout so as to hold the tube section in position against external pressure such as ground water pressure. Suitably the projection is a continuous laterally projecting rib extending from the edge formation spaced from the liner wall. Suitably the edge formations engage so as to form an external groove between the joined edge formations into which bonding material may be placed to bond the strips together. Preferably the bonding material is deposited by welding.

**[0022]** In yet a further aspect, this invention resides broadly in a method of forming a mandrel formed spiral wound pipe, including:

spiral winding plastic strip onto a mandrel;

joining together the adjacent edges of the strip to form a tube;

ejecting a fluid from the mandrel beneath the formed tube to free the formed tube from the mandrel, and

sliding the formed tube from the mandrel.

**[0023]** Suitably the edges of the spiral wound strip are joined together by welding. The edges may also be joined through complementary edge formations or joined with a joining strip. Preferably the spiral wound strip is a ribbed plastic strip made in accordance with an aspect of this invention as defined above and most suitably the joining weld is deposited in the external groove formed between joined edges.

[0024] In order that this invention may be more readily understood and put into practical effect, reference will now be made to the accompanying drawings which illustrate a preferred embodiment of the invention, wherein:

## BRIEF DESCRIPTION OF THE DRAWINGS

[0025] FIG. 1 is a side view of the mandrel assembly with a plastic tube part formed thereon;

[0026] FIG. 2 is a cross-sectional plan view of the mandrel assembly illustrated in FIG. 1;

[0027] FIG. 3 is an end view of the tube forming assembly showing the mandrel and its associated strip feed mechanism;

[0028] FIG. 4 is a cross-sectional side view showing the installation of the plastic lining in a tunnel;

[0029] FIG. 5 is a corresponding view illustrating the relocation of portion of the internal former for the plastic lining;

[0030] FIGS. 6, 7 and 8 are a series of views illustrating the relocation of the internal former for the lining;

[0031] FIG. 9 illustrates the arrangement for feeding concrete to the annular space between the liner and the tunnel;

[0032] FIG. 10 is an end view of the preferred form of plastic strip used to form the tube section;

[0033] FIG. 11 illustrates the junction between complementary edge portions of the strip of FIG. 10;

[0034] FIG. 12 is an end view illustrating the formation of a joining weld between tube sections installed in the tunnel;

[0035] FIG. 13 illustrates a method of post filling voids created after initial grouting, and;

[0036] FIG. 14 illustrates a typical method of aligning one tube section with the next during installation.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0037] According to this embodiment the tunnel is lined to provide smooth plastic lined bore. Since large diameter thin walled plastic pipes or tubes are difficult to handle and transport, the lining tube sections are formed on site as illustrated in FIGS. 1 to 3 utilising extruded plastic strip as illustrated in FIGS. 10 and 11.

[0038] For this purpose lengths of the plastic extrusion 10 is delivered in the form of wound and strapped bales 11, each sufficient to form one liner 12 when wound helically. Each bale 11 is loaded onto a spool 13 on a travelling frame 14 positioned at the outer end of the forming mandrel 15.

[0039] The free end of the extrusion 10 is fed through a strip guide, under a bend roller 17 and a nip roller 18 and then clamped into a start end clamp 19. The mandrel 15 will then be rotated slowly, driven by a variable speed hydraulic drive 20, drawing the strip 10 off the bale 11 and onto the mandrel 15.

[0040] The purpose of the strip 10 guide is to control the helix angle at which the strip 10 is wound onto the mandrel. The bend roller 17 applies a radial force to the strip 10 to bring it into contact with the outer skin of the mandrel and the nip roller 18 pushes the complementary edges 22 and 23 of adjacent strips into engagement so that the inner faces of the coiled strip 10 lie on the mandrel 15.

[0041] When one full turn of the mandrel 15 has been completed a plastic extrusion welder 24 is started to form a weld bead into the formed V-shaped spiral recess 25 formed continuously along the outside of the joined edges 22 and 23.

[0042] Several driving rollers 26 bear on the leading edge 27 of the formed portion of the tube section 30 and drive the rail mounted travelling frame 14 on which the bale 11 is rotatably mounted for advancement as the tube section 30 is formed.

[0043] When the tube section 30 is fully wound and welded each end of the tube section 30 is trimmed square to the axis of the mandrel 15. The start end clamp 19 is then released and low pressure air is injected into a plenum 28 formed between inner and outer skins 29 and 29' of the mandrel. The air escapes from the mandrel through apertures in the outer skin 29 causing the formed plastic tube section 30 to swell slightly so that it is easily removed from the mandrel 15.

[0044] A cradle is positioned at one end of the mandrel 15 so that as the completed tube section 30 is slid from the mandrel it is seated in a respective cradle. Suitably there are three cradles along the length of the tube section 30 on rails which will allow the tube section 30 to be moved clear of the mandrel 15.

[0045] To maintain the tube sections 30 in the form of the liners 12 required, when each tube section 30 is slid from the mandrel 15 a series of supporting spiders 32 is installed in the tube sections 30, each being aligned with a cradle. A crane with a spreader bar and straps will lift each tube section 30 to a storage yard.

[0046] The formed tube sections 30 are inspected to ensure that they are free of dirt or any other foreign material and then each is craned to the collar of the shaft using a spreader bar and straps for installation as a liner 12. Each tube sections 30 is lowered into the tunnel 40 until it is positioned over the top of the tunnel rails 36 and aligned with a tube carrier 37 thereon.

[0047] In this embodiment, each tube section 30 is suitably 9 metre long and is transported through the tunnel 40 to its installation point on the rail mounted tube carrier 37. The tube carrier 37 will carry each tube sections 30 on cantilevered forks 42 through the tunnel 40 for positioning adjacent the previously installed liner 12. Suitably the forks 42 is able to slew left to right, cross travel, raise and lower and articulate upwards and downward to enable each liner 12 to be aligned and correctly mated to the previously installed tube section 30.

[0048] Each tube section 30 is supported internally with spiders 32 to prevent it buckling while it is being transported and positioned in the tunnel 40. The leading edge of the tube section 30 is protected by buffers temporarily installed thereon to protect the tube section 30 from touching any part of the excavation on its journey through the tunnel 40.

[0049] The tube section 30 will then be spigoted into the socket 43 formed about the end of the previously installed liner 12, as illustrated in FIG. 14 to provide quick and accurate co-axial alignment of the tube sections 30 so as to form a continuous liner 12 through the tunnel 40. The socket is suitably provided with apertures therethrough so as to prevent formation of voids about the installed liner.

[0050] The tube sections 30 are welded at their junction once the concrete has been placed and the internal form assembly 38 removed. Welding is carried out using a rotating welding arm 44 fitted with extrusion welders set at the appropriate radius or biased to the desired proximal position to effect the weld.

[0051] As illustrated in FIGS. 6 to 8, the internal form assembly 38 consists of three base wall panels 39 and a collapsible obvert form assembly 46 which cooperate to provide a cylindrical outer wall when in their interlocked operative position. The obvert form assembly 46 may be collapsed by folding at the pivot joints 55 between its panel sections and lifted free from the base wall panels 39 by a mobile form carrier 47 supported on the base wall panels 39.

**[0052]** After the tube section 30 has been positioned to form a liner 12, the remote one of the three base wall panels 39 is lifted by an elevated rail 56 of the form carrier, tilted about 90° to the position illustrated in FIG. 6 and then transported to the opposite end of the rail 56 where it is lowered into position in the base of the newly installed tube section 30, see FIG. 5.

**[0053]** Two spud bar holes 57 are then formed through the liner 12 using the holes in the invert form segment as a template, to allow the spud bars to locate the invert form and liner 12 to supporting segments 58 installed during excavation.

**[0054]** This process is repeated until all base wall panels 39 have been relocated to allow the form carrier 47 to travel thereacross carrying the collapsed obvert form assembly 46 into the next tube section 30 to be installed where it is extended to cooperate with the base wall panels 39 to hold the tube section 30 in its designed shape during the concreting operation. As the obvert form assembly 46 and carrier 47 move forward the tube carrier 37 will retreat and the support spiders 32 will be removed and the tube carrier 37 will be transported out to receive another liner.

**[0055]** Upon installation of the internal form assembly 38 the liner 12 is made rigid whereafter the side and top of the liner 12 is spudded to the excavation so that it is held in its design position while concreting. Typically six spuds will be used around the circumference of the liner 12 every three linear metres.

**[0056]** As the tube carrier 37 and its locomotive 60 return for another liner 12 the concrete hands will prepare for the next tube section installation by removing the next 9 metres of excavation rail track 36 and washing down the walls.

**[0057]** A slick line 62 for concrete delivery is installed along the length of the pour in the tunnel crown. It is held in place by brackets 63 each with a roller assembly 64 to enable the slick line 62 to move easily. See FIG. 9.

**[0058]** Concrete is delivered to a concrete pump 65 on the surface and pumped down a drophole 66. Suitably a plurality of dropholes are formed about 300m apart on the surface

along the tunnel 40. The distance between dropholes may vary, depending on surface infrastructure and/or liner 12 installation requirements and the like.

**[0059]** The slick line 62 underground is supported in a folded manner on a rail mounted scissors type support onto which the slick line is gathered as the pour progressively fills the cavity between the tube sections 30 and the tunnel wall. This arrangement has the advantage that it allows a continuous pour for the full length of each installed liner.

**[0060]** Suitably the concrete to be used for the backfill of the tunnel liners will be low shrink, flowable, self compacting, high strength (40Mpa) and have a low water/cement ratio. Such a mix design will allow ease of placement, structural integrity and reduce backfill/proof grout to a minimum.

**[0061]** During installation, spud bar holes are drilled through the liner 12 to extend into the surrounding tunnel wall. This may create voids in the finished concrete grout. These are filled through a grout pipe 70 as illustrated in FIG. 13. The pipe 70 provided with internal air bleed/tell tale tube 71 is placed in the spud bar hole and held in place with a thrust leg 72. The air bleed tube 71 is extended to within 20mm of the top of the hole and as grout is pumped into the void air is expelled through the air bleed tube 71 until the void has been filled, whereupon grout will appear from the tube 71. Grouting at each hole may be repeated to ensure that there has been no grout leakage and any voids have been successfully filled. When routing has been completed, the holes in the liner 12 are capped and welded. On completion of all the welding, spark testing of the completed tunnel 40 will occur.

**[0062]** The formed lined tunnel will have a smooth cylindrical internal surface with a 2400mm inside diameter and a liner wall thickness not less than 3mm. The liner will be watertight from both the inside and outside and able to withstand an external hydrostatic pressure when grouted/concreted into the tunnel 40.

**[0063]** It will be seen from FIGS. 10 and 11 that the strip 10 has a series of equally spaced T shaped ribs 75 formed integrally on its outer surface which interlock with the concrete grout to resist the external hydrostatic pressures which may be applied in use.

**[0064]** Furthermore the complementary edge formations 22 and 23 are so formed that each has a return flange 77 and 78 formed integrally therewith so that the joined edges also interlock with the grout to ensure that the liner has equal resistance to external pressures throughout its length.